

INFESTATIONS OF *Mayetiola* spp. (Diptera : Cecidomyiidae) IN BREAD WHEAT, DURUM WHEAT AND BARLEY : RESULTS OF FIVE ANNUAL SURVEYS IN THE MAJOR CEREAL GROWING REGIONS OF MOROCCO

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INTRODUCTION

Midges in the genus *Mayetiola* (Diptera : Cecidomyiidae) have been recognized as a serious pest of cereals in Morocco for many years (MESNIL 1934, BALACHOWSKY & MESNIL 1935, JOURDAN 1937). In bread wheat (*Triticum aestivum* L.) and durum wheat (*Triticum turgidum* L. var. durum) the pest has been recognized as the Hessian fly, *Mayetiola destructor* (Say).

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However, in barley (*hordeum vulgare* L.) the identity of the pest has been debated, but GAGNÉ et al. (1991) confirmed that in Morocco the pest in barley was *M. hordei* (Kieffer), the "barley stem gall midge". *M. destructor* occurs on barley at low frequency.

In the North American Midwest, where Hessian fly infestations have been followed more extensively, serious Hessian fly infestations are somewhat localized and seem to occur in outbreak cycles. MCCOLLOCH (1923) described eight outbreaks of Hessian fly in Kansas between 1870 and 1917 and indicated that the most serious infestations were found in the eastern half of the state. More recently, surveys of Hessian fly infestations have recorded the highest infestations in the central parts of Ohio (LAFEVER et al. 1980), Kansas (HATCHETT & OPPENLANDER 1981), Oklahoma (HATCHETT et al. 1981), and the northeastern counties of South Dakota (STEIGER et al. 1982). Surveys in Washington State (PIKE et al. 1983) and South Carolina (CHAPIN et al. 1989) recorded highest infestations on the respective coastal plains and in Washington they were also found in irrigated fields in the inland regions.

Although the cereal midges, *Mayetiola* spp., are widespread in North Africa, the most serious damage has been observed in Morocco, particularly in the westcentral semi-arid coastal region. Preliminary surveys were carried out in 1984 and 1985, and lead to this more extensive survey initiated in 1986. This study was undertaken: 1. to determine the distribution of *Mayetiola* spp. infestations in Morocco, particularly in the westcentral semi-arid region, 2. to compare *Mayetiola* spp. infestations on the three major types of cereals: bread wheat, durum wheat and barley, 3. to observe the annual variation in *Mayetiola* spp. infestations and 4. to measure *Mayetiola* spp. infestations for later economic analysis of losses due to *Mayetiola* spp.

MATERIALS AND METHODS

Cereal fields in the seven provinces of the westcentral semi-arid region were surveyed annually for *Mayetiola* spp. over the 5 year period; 1986-90. The surveys were conducted in April, after the second generation larvae and flaxseed were present. Cereal fields along the road were sampled every 10 or 20 km, while driving a route selected to include the important cereal growing areas of the seven provinces. The route was similar each year and included two loops, the first loop started at Settât, continued to Sidi Bennour, Safi, Marrakech, and back to Settât, and the second loop started at Marrakech, continued to El Kalâa Srarhna, Fqih ben Salah, Khouribga, Ben Ahmed and back to Settât, (Fig. 1).

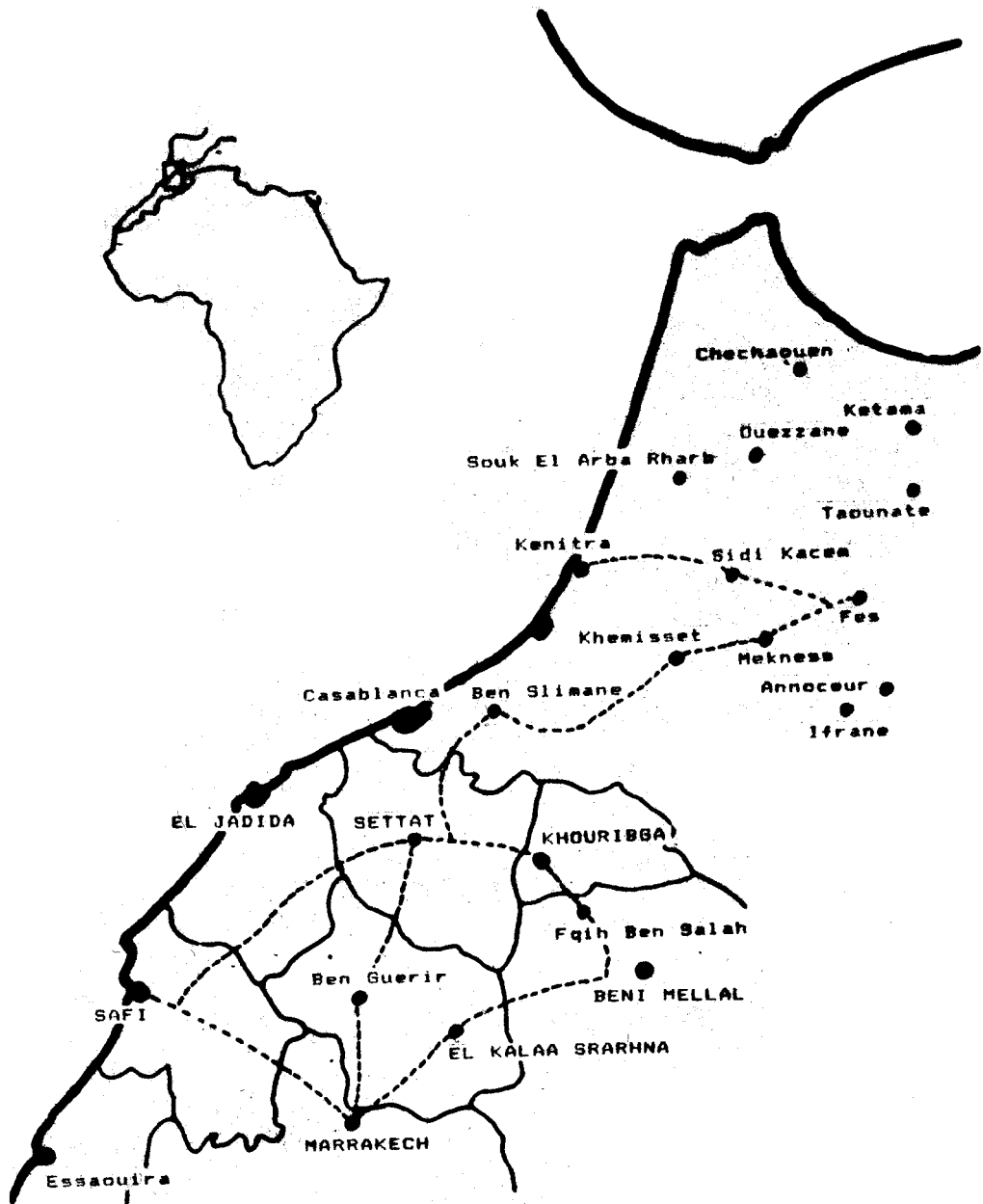


Fig. 1. : Map of North and Central Morocco, North Africa, including the main cereal growing regions where cecidomyiid surveys were conducted. Boundaries of seven provinces (upper case lettering) in the Westcentral semi-arid region are outlined (solid lines) and the survey routes are indicated (dashed lines). Other cities mentioned in the text are also identified.

Table 1. : *Mayetiola* spp. infestations in fields of three cereals surveyed for 5 years in Morocco.

	Number fields sampled	Percent Fields		
		infested	Over 20% tillers infested	Over 50% tillers infested
Bread Wheat				
1986	61	87	72	36
1987	56	79	25	9
1988	59	86	66	27
1989	63	94	92	30
1990	73	93	67	32
MEAN	312	88	65	27
Durum Wheat				
1986	57	88	61	30
1987	36	67	22	3
1988	61	79	41	7
1989	62	90	89	39
1990	69	94	49	26
MEAN	285	85	55	22
Barley				
1986	59	78	56	25
1987	55	75	35	4
1988	71	72	44	18
1989	62	85	85	40
1990	72	90	54	24
MEAN	319	80	55	23

Table 2. : *Mayetiola* spp. infestations in fields of three cereals surveyed in seven provinces over 5 years in Morocco.

	Number fields sampled	Percent Fields		
		infested	Over 20% tillers infested	Over 50% tillers infested
Bread Wheat				
Settat	44	100	91	48
El Jadida	41	98	90	46
Safi	47	100	74	45
Marrakech	33	64	33	6
El Kelâa Srahna	58	90	60	16
Beni Mellal	54	80	59	17
Khouribga	35	80	40	11
MEAN	312	88	65	27
Durum Wheat				
Settat	44	98	75	36
El Jadida	40	98	83	35
Safi	47	96	70	45
Marrakech	25	68	24	4
El Kelâa Srahna	58	83	43	9
Beni Mellal	40	78	48	10
Khouribga	31	65	26	6
MEAN	285	85	55	22
Barley				
Settat	48	100	85	42
El Jadida	42	100	86	31
Safi	53	92	79	45
Marrakech	37	38	11	3
El Kelâa Srahna	58	71	29	7
Beni Mellal	38	68	42	13
Khouribga	43	84	44	12
MEAN	319	80	55	23

of each variable was highly significant while the interactions were significant for one (Table 4). The interactions were not significant for the two proportional variables (insects per tiller or plant), and the trends in the interaction means were similar to those in the main effect means. The *Mayetiola* spp. infestations were significantly higher in bread wheat than in durum wheat or barley and this trend was present in each province. The interactions were significant for one of the two percent variables (percent tillers or plants infested), and the trends among interaction means were not consistent with the main effect means in all provinces. The main effects means suggest bread wheat had significantly higher infestations than did the other cereals, but examination of the interaction means indicates that this trend was present only in the three most inland provinces, Marrakech, El Kelâa Srahna and Beni Mellal. In the other four provinces infestations in the three cereals were not significantly different. This discrepancy between the proportional and percent variables occurs because *Mayetiola* spp. numbers per tiller or plant are frequently quite high (sometimes over 100 per tiller) in bread wheat while they seldom exceed ten or twenty in the other cereals. All four *Mayetiola* spp. variables indicate that the highest infestations occur in the three provinces on the coastal plain, Settat, El Jadida and Safi. The lowest infestations were found in the southern province, Marrakech, and intermediate infestations were found in the inland provinces, El Kelâa Srahna, Khouribga and Beni Mellal.

The third analysis of variance, year by province, was conducted for each cereal separately. In these analyses, the main effects of province were highly significant for all variables and for all three cereals. The main effects of year were highly significant for all variables for the wheats, but in barley it was not significant for the two proportional variables (Tables 5, 6 and 7). Since the interactions between year and province were significant for many variables, the interaction means with 95% confidence limits for each year by province are presented (Table 8 and Figs 1-6). The pattern of year to year variation was different in different provinces and for the different cereals and are probably related to local variations in rainfall, temperature, planting date and sampling variability. In most cases the drought year, 1987, was associated with very low *Mayetiola* spp. infestations. In all three cereals, *Mayetiola* spp. infestations were clearly highest in the three coastal provinces, Settat, El Jadida and Safi. The lowest infestations were observed in the southern province, Marrakech, and intermediate infestations were recorded in the other inland provinces. The confidence limits are much wider for the percent variables than for the fractional variables.

In the analysis of variance of the 1990 survey, cereal by province, the main effects of each factor were highly significant, and the interactions were not significant (Table 9). Again the highest **Mayetiola** spp. infestations were observed in Settât, El Jadida and Safi provinces, but they were not clearly separated from the infestations in the four northern provinces of Khemisset, Meknes, Sidi Kacem and Kenitra. Clearly there were very significant **Mayetiola** spp. infestations in the northern cereal producing areas in 1990. In this survey the percent variables indicated that **Mayetiola** spp. infestations were not significantly different among the three cereals, although the proportional variables indicate the intensity of infestation was slightly lower in barley.

In the province of Essaouira, sampled in 1987 only, 67 percent of the wheat fields were infested (n=9) and 49 percent of the barley fields were infested (n=6). The wheat and barley fields averaged 55 and 49 percent tillers infested or 2.4 and 2.6 insects per plant, respectively.

DISCUSSION

This survey has documented that **Mayetiola** spp. infestations are very serious in Morocco. The highest infestations occur in the central coastal provinces of Settât, El Jadida and Safi, but serious infestations are found throughout the cereal growing regions of Morocco.

In 1990, **Mayetiola** spp. infestations in the important northern cereal growing provinces of Khemisset, Meknes, Sidi Kacem and Kenitra were almost as serious as they were further south. This region was not surveyed in detail in the previous four years so we can not document that it is this serious every year. However, one should note that in the westcentral region, **Mayetiola** spp. infestations did not change greatly from year to year, particularly in barley. Also, a preliminary survey trip into the northern region in 1984 (unpublished report) recorded "heaviest" infestations between Rabat and Khemisset, "heavy" infestations near Meknes, and "increased" infestations between Souk El Arba Rharb, Sidi Kacem and Kenitra. Light to moderate infestations were found between Ifrane and Annoceur, and from Taounate to Ketama, Chechaouen and Ouezzane. A total of 62 bread and durum wheat fields were sampled, 87 percent were infested and 52 percent had economic infestations. Eleven barley fields were sampled and 27 percent had economic infestations.

Mayetiola spp. infestations of 1990 are probably not unusual for northern Morocco, but the damage was unusually visible this year. We observed many

fields with obvious visible **Mayetiola** spp. damage and a few fields that were completely destroyed. In 1990, the northern regions experienced an extended dry period in January and February which prevented the cereal from re-tillering to replace those killed by **Mayetiola** spp. In other years there is more rainfall and cereals are able to re-tiller and hide the damage.

The intensity and annual variation of **Mayetiola** spp. infestations in Morocco were different from those observed in the North American Midwest, where most **Mayetiola** spp. research has been conducted. In the Midwest, infestations were generally not as severe and not as persistent across years (LAFEVER et al. 1980, HATCHETT & OPPENLANDER 1981, HATCHETT et al. 1981, STEIGER et al. 1982).

The intensity and annual variation of **Mayetiola** spp. infestations in Morocco seem to have some similarities with infestations in the southeast of North America. In South Carolina infestations averaged 95, 98 and 100 percent of fields infested on the coastal plain in a three year survey, and 65, 21 and 57 percent of the fields had economic infestations (CHAPIN et al. 1989). For Morocco the comparable numbers were 88 percent fields infested and 65 percent fields with economic infestations over a five year period. In South Carolina, infestations were found to be significantly higher on the southern coastal plain than on the northern coastal plain or the upper Piedmont. In Morocco the infestations were higher on the coastal plain, particularly the southern coastal plain, than in the inland provinces. However, in Morocco the rainfall is much lower than in South Carolina and there are only two main generations (LHALOUI 1986) compared to up to five in South Carolina (CHAPIN et al. 1989).

The pattern of **Mayetiola** spp. infestations in Morocco also seems to have some similarities with infestations in Washington state. There **Mayetiola** spp. infestations were highest on the Western coastal plain and in the irrigated regions of eastern Washington (PIKE et al. 1983). The coastal plain of Washington is much more humid than in the eastern region. We did not make detailed observations on infestations of irrigated versus non-irrigated fields, but the general impression was that infestations might be lower in irrigated than in non-irrigated fields in Morocco.

In Morocco, the most serious **Mayetiola** spp. infestations were in the more humid coastal plains. DURAND (1967) also observed that, **Mayetiola** spp. infestations were heaviest along the Moroccan Atlantic coast. This pattern has

also been observed in Algeria and Tunisia (unpublished data). In the inland regions the infestations are not as severe and may be more sporadic.

In barley, the magnitude of *Mayetiola* spp. infestations was not significantly different from that on wheat in some provinces of Morocco. In addition, grain yield losses due to *Mayetiola* spp. infestations in barley were not much different from those observed in wheat (LHALOUI et al. 1992). However, *Mayetiola* spp. damage in barley was less visible, since the plants formed galls around the insects and were not stunted.

This is in contrast with the situation in North America, where barley is seldom attacked seriously. However, we are aware of two recent Hessian fly infestations in barley : in Georgia (G.D. Buntin, personal communication) and in Washington state (K.S. Pike, personal communication). In these situations, the damage to barley was similar to that in wheat, the plants were stunted and no galls were produced.

MESNIL (1934) described *M. mimeuri* from cereal collected in Morocco, but the taxonomic status of this species has been in question (see review by GAGNÉ et al. 1991). The validity of the species has now been verified, but the name *M. mimeuri* is now a junior synonym of *M. hordei*. *M. hordei*, is host specific to barley, 96% of the *Mayetiola* specimens collected from barley (n=478), were *M. hordei*, while 99.5% of *Mayetiola* specimens collected from wheat (n=655) were *M. destructor* (GAGNÉ et al. 1991). In addition to microscopic anatomical differences between *M. hordei* and *M. destructor*, *M. hordei* produces galls on barley plants, while *M. destructor* does not, even when it infests barley. *M. hordei* does not occur in North America.

Analysis of the four *Mayetiola* spp. variables indicates that trends in the two "percent variables" (percent tillers or plants infested) were not always the same as trends in the two "fractional variables", (insects per tiller or per plant). The percent variables are probably more useful for evaluating plant yield responses, because the first one or two insects on the tiller causes most of the damage to that tiller. The fractional variables are probably more useful for following population dynamics (particularly when converted to square meter area basis), because these numbers relate to the number of individuals in the generation.

This survey was carried out using procedures similar to those used in other published surveys. Only the Ohio survey differs significantly in that they utilized plant samples collected by certified seed field inspectors as the field samples. In

our survey, 1025 fields throughout Morocco were sampled over five years. The North American Midwest surveys involved 350 to ca. 1000 fields over three to 13 years (LAFEVER et al. 1980, HATCHETT & OPPENLANDER 1981, HATCHETT et al. 1981, STEIGER et al. 1982). The Washington survey involved 403 fields over five years (PIKE et al. 1983) and the South Carolina survey involved 108 fields over three years (CHAPIN et al. 1989).

Fields were selected for sampling along routes which were intended to be representative of the provinces of the region. It would therefore be useful to examine the route to see how representative it was. It appears that the provinces of Settat, Safi and El Kelâa Srahna were sampled most completely and the data should be reasonably representative. It appears that significant regions of El Jadida, Marrakech, Beni Mellal and Khouribga were not sampled. In the last three provinces the unsampled non-mountainous cereal growing areas are agronomically similar to the regions that were sampled and therefore the data should be reasonably representative. In El Jadida, we did not sample the less productive cereal growing regions closer to the city and thus the data may not be completely representative of this province. At this time, we have no information to suggest that road side fields are different from non-road side fields in any biological or sociological factor. We believe these estimates can be taken as reasonably representative of cereal fields in the provinces listed.

The estimates of *Mayetiola* spp. infestations reported here will be used to estimate yield losses and to determine the economic impact of *Mayetiola* spp. in Morocco. These considerations will be reported elsewhere.

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Table 3. : Analysis of variance of *Mayetiola* spp. populations in three cereals during five sample years and the main effect means for years and cereal type averaged over seven provinces.

	Insects per tillers	Percent tillers infested	Percent plants infested	Insects per plant
ANOVA Table :				
Treatments (14df) ^a	6.23***	11.47***	5.89***	7.14***
Year Main Effect (4df) ^a	10.62***	34.98***	14.32***	11.60***
Cereal Main Effect (2df) ^a	12.33***	5.27**	7.65***	16.45***
Interactions (8df) ^a	2.57**	1.35 NS	1.29 NS	2.63**
Error Mean Square (901df) ^a	0.046	5.535	8.467	0.127
CV	93%	48%	48%	81%
Year Main Effect Means ^b				
1986	0.84 AB	25.20 B	44.04 A	2.13 AB
1987	0.37 D	10.12 D	21.40 C	0.91 C
1988	0.64 C	17.09 C	31.59 B	1.59 B
1989	0.67 BC	37.32 A	37.74 AB	1.76 AB
1990	0.88 A	25.60 B	45.62 A	2.34 A
Cereal Main effect Means ^b				
Bread Wheat	0.88 A	26.37 A	43.00 A	2.40 A
Durum Wheat	0.64 B	21.22 B	33.80 B	1.61 B
Barley	0.56 B	20.96 B	32.57 B	1.36 B

^a F - values : NS not significant ($P \leq 0.05$), * significant ($P \leq 0.05$), ** significant ($P \leq 0.01$), *** significant ($P \leq 0.001$).

^b Means within columns followed by the same letter are not significantly different ($P \leq 0.05$) : least significant difference test.

Table 4. : Analysis of variance of *Mayetiola* spp. populations in three cereals and in seven provinces with the interaction means for cereal type and province averaged over five years.

	Insects per tiller	Percent tillers infested	Percent plants infested	Insects per plant				
ANOVA Table :								
Treatments (20df) ^a	21.00***	19.20***	23.16***	21.05***				
Province Main Effect (6df) ^a	51.40***	59.04***	68.39***	50.28***				
Cereal Main Effect (2df) ^a	18.54***	7.26***	12.34***	24.07***				
Interactions (12df) ^a	1.28 NS	1.48 NS	2.69***	1.49 NS				
Error Mean Square (895df) ^a	0.035	4.594	6.131	0.096				
CV	81%	44%	41%	70%				
Interaction Means - cereal type by province :								
	Settat	El Jadida	Safi	Marrakech	El Kelâa	BeniMellal	Khourbga	MEANS
Insects per tiller^b								
Bread Wheat	1.51a	1.63a	1.63a	0.35ab	0.62ab	0.51ab	0.35ab	0.90 A
Durum Wheat	1.00ab	1.19ab	1.45ab	0.17ab	0.35ab	0.35ab	0.20ab	0.64 B
Barley	1.29ab	0.86ab	1.09ab	0.05 b	0.23ab	0.23ab	0.35ab	0.55 B
MEANS	1.26A	1.20A	1.37A	0.18C	0.39B	0.37B	0.32BC	
Percent tillers infested^b								
Bread Wheat	43.49a	42.56a	37.81a	9.69de	21.87b	19.98bc	14.37bcd	26.62A
Durum wheat	34.75a	37.81a	34.28a	7.41 e	15.73bcd	15.73bcd	9.30 de	21.31 B
Barley	43.89a	37.81a	35.85a	2.50 f	9.96 de	12.99 cde	15.08bcd	21.68 B
MEANS	40.78A	39.37A	36.14A	5.90C	15.50B	16.20B	13.19B	

Table 4. (continued)

	Settat	El Jadida	Safi	Marrakech	El Kelâa	Beni Mellal	Khoubga	MEANS
Percent plants infested ^b								
Bread Wheat	66.08a	67.72a	63.64a	19.88def	35.48bc	31.83cd	24.00cde	43.57A
Durum Wheat	52.58a	62.36a	51.13ab	12.62f	24.91cde	24.60cde	15.97 ef	33.56 B
Barley	68.22a	65.59a	54.35a	3.24g	16.31ef	15.65 ef	27.20cde	32.29 B
MEANS	62.52A	65.29A	56.49A	10.30C	25.03B	23.91B	22.93B	
Insects per plant ^b								
Bread Wheat	4.25ab	4.89a	4.89a	1.00efg	1.82de	1.34ef	0.91fg	2.44A
Durum Wheat	2.55 cd	3.37abc	3.57abc	0.48 h	1.04efg	0.95 fg	0.55jh	1.59 B
Barley	3.57abc	2.39 cd	2.80 bcd	0.15 h	0.58 gh	0.58 gh	0.86fg	1.34 B
MEANS	3.41A	3.43A	3.66A	0.48C	1.10B	0.93B	0.79BC	

^a F-values : NS not significant ($P \leq 0.05$), * significant ($P \leq 0.05$), ** significant ($P \leq 0.01$), *** significant ($P \leq 0.001$).

^b Interaction means within each variable followed by the same lower case letter are not significantly different ($P \leq 0.05$); least significant difference test. Overall means within columns or rows followed by the same upper case letter are not significantly different ($P \leq 0.05$) : least significant difference test.

Table 5. : Analysis of variance of *Mayetiola* spp. populations in bread wheat in five sample years and seven provinces with main effect of means for year and province.

	Insects per tillere	Percent tillers infested	Percent plants infested	Insects per plant
ANOVA Table :				
Treatments (34df) ^a	6.13***	6.18***	4.98***	6.14***
Year Main Effect (4df) ^a	7.04***	11.70***	5.57***	7.14***
Province Main Effect (6df) ^a	18.69***	15.30***	14.38***	17.95***
Interactions (24df) ^a	2.10**	1.97**	1.85*	2.34***
Error Mean Square (277df) ^a	0.036	3.76	5.45	0.099
CV	70%	37%	37%	59%
Year Main Effect Means ^b				
1986	1.06A	27.74 B	48.13 A	2.84 AB
1987	0.50 C	12.93 C	26.81 B	1.23 C
1988	1.15A	26.93 B	48.02 A	3.16 A
1989	0.72 BC	36.85 A	41.41 A	2.01 B
1990	0.99 AB	27.67 B	49.34 A	2.88 AB
Province Main Effect Means ^b				
Settat	1.43A	40.77 A	63.00 A	3.94 A
El Jadida	1.52 A	41.03 A	65.18 A	4.61 A
Safi	1.66 A	37.37 A	63.74 A	4.88 A
Marrakech	0.35 C	10.47 C	20.11 C	0.98 C
El Kelâa Srarhna	0.65 B	21.35 B	36.21 B	1.91 B
Beni Mellal	0.52 BC	21.00 B	32.44 B	1.36 BC
Khouribga	0.40 BC	16.34 B	26.27 BC	1.02 C

^a F - values: NS not significant ($P \leq 0.05$), *significant ($P \leq 0.05$), ** significant ($P \leq 0.01$), *** significant ($P \leq 0.001$).

^b Means within columns followed by the same letter are not significantly different ($P \leq 0.05$) : least significant difference test.

Table 6. : Analysis of variance of *Mayetiola* spp. populations in durum wheat in five sample years and seven provinces with main effect means for year and province.

	Insects per tiller	Percent tillers infested	Percent plants infested	Insects per plant
ANOVA Table :				
Treatments (34df) ^a	5.62***	6.06***	5.05***	5.49***
Year Main Effect (4df) ^a	4.10**	15.85***	5.62***	5.34***
Province Main Effect (6df) ^a	18.84***	14.84***	15.39***	16.26***
Interactions (24df) ^a	1.99**	1.33NS	1.51NS	2.18**
Error Mean Square (250df) ^a	0.032	3.804	5.551	0.088
CV	81%	41%	40%	71%
Year Main Effect Means ^b				
1986	0.72AB	22.34 B	40.01 A	1.84 AB
1987	0.56 BC	12.54 C	25.16 B	1.33 BC
1988	0.41 C	12.80 C	23.89 B	0.96 C
1989	0.69AB	37.76 A	38.33 A	1.82 AB
1990	0.87 A	23.77 B	42.51 A	2.28 A
Province Main Effect Means ^b				
Settat	0.95 A	32.56 A	50.34 A	2.40 B
El Jadida	1.17 A	37.33 A	59.70 A	3.24 AB
Safi	1.43 A	33.47 A	50.48 A	3.52 A
Marrakech	0.17 B	9.01 B	13.52 C	0.50 B
El Kelâa Srarhna	0.37 B	15.50 B	26.06 B	1.08 B
Beni Mellal	0.39 B	16.72 B	25.77 B	1.02 B
Khouribga	0.22 B	9.88 B	16.40 BC	0.56 B

^a F - values : NS not significant ($P \leq 0.05$), *significant ($P \leq 0.05$), ** significant ($P \leq 0.01$), *** significant ($P \leq 0.001$).

^b Means within columns followed by the same letter are not significantly different ($P \leq 0.05$) : least significant difference test.

Table 7. : Analysis of variance of *Mayetiola* spp. populations in barley in five sample years and seven provinces with main effect means for year and province.

	Insects per tiller	Percent tillers infested	Percent plants infested	Insects per plant
ANOVA Table :				
Treatments (33df) ^a	6.15***	9.57***	9.155***	6.82***
Year Main Effect (4df) ^a	1.46 NS	12.41***	1.97 NS	1.26 NS
ProvinceMain Effect (6df) ^a	28.07***	35.61***	43.20***	32.23***
Interactions (23df) ^a	0.84 NS	1.71*	1.03NS	0.84 NS
Error Mean Square (285df) ^a	0.027	3.752	5.463	0.071
CV	87%	42%	41%	72%
Year Main Effect Means ^b				
1986	0.47 A	18.32 BC	33.35 AB	1.18 A
1987	0.47 A	13.89 C	27.77 B	1.18 A
1988	0.55 A	15.25 C	28.72 B	1.33 A
1989	0.55 A	35.75 A	30.95 AB	1.30 A
1990	0.68 A	22.23 B	39.65 A	1.67 A
Province Main Effect Means ^b				
Settat	1.28 A	42.11 A	67.15 A	3.57 A
El Jadida	0.88 B	38.00 A	64.24 A	2.38 B
Safi	1.08 AB	35.85 A	54.81 A	2.81 A B
Marrakech	0.07 D	3.29 D	3.44 D	0.16 D
El Kelâa Srahna	0.22 CD	8.89 C	16.41 C	0.57 C
Beni Mellal	0.23 CD	13.00 BC	15.50 C	0.60 C
Khouribga	0.37 C	16.58 B	28.04 B	0.88 C

^a F - values : NS not significant ($P \leq 0.05$), * significant ($P \leq 0.05$), ** significant ($P \leq 0.01$), *** significant ($P \leq 0.001$).

^b Means within columns followed by the same letter are not significantly different ($P \leq 0.05$) : least significant difference test. Mean separations for percent plants infested by year are not supported by a significant F-test.

Table 8. : Percent tillers infested with *Mayetiola* spp. for three cereals in seven provinces over five sample years.

Province Year	Bread Wheat ^a			Durum Wheat ^a			Barley ^a		
	CL	<Mean>	CL	CL	<Mean>	CL	CL	<Mean>	CL
Settat									
86	26.72	49.55	79.20	16.08	31.49	51.81	17.96	34.05	55.04
87	6.77	18.62	35.87	1.18	8.92	22.26	13.46	30.14	53.12
88	21.13	42.30	70.50	14.99	30.25	50.56	23.64	43.09	68.16
89	23.61	43.89	70.22	24.70	47.44	77.33	29.68	53.91	85.13
90	25.36	45.65	71.69	18.56	35.36	57.33	26.46	47.30	73.99
El Jadida									
86	17.80	32.41	51.19	23.24	43.62	70.18	22.97	40.99	64.03
87	17.81	40.09	70.96	5.88	17.66	35.20	9.61	21.85	38.72
88	23.90	47.72	79.46	7.88	17.23	29.91	17.67	34.16	55.83
89	26.28	50.98	83.58	25.11	52.58	89.83	22.65	44.70	73.95
90	27.03	50.12	80.11	22.25	43.22	70.88	21.07	38.82	61.77
Safi									
86	22.88	42.56	68.11	18.89	36.21	58.91	29.84	54.65	86.73
87	5.11	10.42	17.39	0.96	3.54	7.18	10.85	20.90	34.02
88	18.59	35.12	56.67	7.92	15.97	26.59	11.29	20.62	32.57
89	26.33	48.42	77.01	29.89	57.22	93.14	24.16	44.02	69.63
90	30.49	57.06	91.70	26.40	51.13	83.73	26.86	49.27	78.24
Marrakech									
86	6.22	12.18	19.91	4.76	10.49	18.18	0.00	0.59	1.48
87	2.12	4.95	8.69	1.57	4.02	7.28	1.78	4.24	7.48
88	11.19	22.23	36.80	0.82	3.93	8.56	1.40	3.37	5.93
89	1.32	4.06	7.87	5.63	16.98	33.87	4.47	10.76	19.45
90	1.71	4.52	8.33	2.59	7.23	13.95	0.00	0.28	1.14

Table 8 : (continued).

Province Year	Bread Wheat ^a			Durum Wheat ^a			Barley ^a		
	CL	<Mean>	CL	CL	<Mean>	CL	CL	<Mean>	CL
El Kelâa Srahna									
86	6.92	33.34	210.24	0.10	4.02	10.76	--	--	--
87	2.94	6.13	10.25	4.74	10.22	17.52	1.62	3.67	6.29
88	15.63	28.70	45.53	6.34	12.47	20.44	1.92	4.15	7.02
89	20.86	37.44	58.66	15.06	28.27	45.40	12.68	22.81	35.74
90	8.58	15.89	25.27	6.36	12.54	20.60	5.47	10.29	16.45
Beni Mellal									
86	14.26	26.25	41.69	8.09	17.66	30.63	2.11	5.00	8.84
87	7.38	14.05	22.67	7.19	15.81	27.49	2.94	6.62	11.49
88	6.29	12.18	19.80	4.10	8.61	14.54	2.97	6.34	10.74
89	14.37	27.73	45.24	14.20	28.70	48.01	26.30	50.41	82.08
90	12.65	23.90	38.50	6.94	14.29	24.01	6.92	13.44	21.90
Khouribga									
86	3.85	11.25	22.02	1.42	4.20	8.02	4.09	8.18	13.47
87	3.30	6.78	11.29	4.07	9.50	16.88	7.08	13.21	21.07
88	4.96	10.36	17.48	0.00	0.96	2.27	7.38	14.29	23.25
89	23.76	47.44	79.00	14.72	31.26	53.59	16.77	33.34	55.32
90	6.85	13.67	22.61	5.31	11.32	19.33	7.10	13.98	22.95

^a Means with lower and upper 95% Confidence Limits.

Table 9. : Analysis of variance of *Mayetiola* spp. populations in three cereals and twelve provinces with the main effect means for cereal type and province, 1990 survey.

	Insects per tiller	Percent tillers infested	Percent plants infested	Insects per plant
ANOVA Table :				
Treatments (38df) ^a	5.09***	4.84***	4.13***	4.49***
Prov. Main Effect (12df) ^a	13.95***	13.56***	10.98***	11.53***
Cereal Main Effect (2df) ^a	5.53***	1.30 NS	0.87 NS	7.97***
Interactions (24df) ^a	0.64 NS	0.78 NS	0.98 NS	0.69 NS
Error Mean Square (269df) ^a	0.118	0.175	0.190	0.716
CV	24%	32%	28%	42%
Province Main Effect Means ^b				
Settat	1.59 BC	37.64 AB	65.07 A	4.90 BC
El Jadida	1.71 B	40.50 AB	75.38 A	6.05 AB
Safi	2.85 A	45.13 A	65.07 A	9.02 A
Marrakech	0.15 G	1.79 F	3.35 D	0.41 F
Ben Guerir ^c	0.70 DEF	11.53 DE	21.28 C	2.26 DE
El Kelâa Srarhna ^c	0.27 FG	7.43 E	19.61 C	0.98 EF
Beni Mellal	0.42 EFG	14.49 CD	28.51 BC	1.28 DEF
Khouribga	0.30 FG	10.69 DE	22.44 C	0.87 EF
Ben Slimane	0.76 DEF	15.03 CD	27.12 BC	2.52 DE
Khemisset	0.98 CDE	26.54 ABC	51.24AB	2.81 CD
Meknès	0.84 DE	26.61 ABC	46.75AB	2.30 DF
Sidi Kacem	0.61 DEFG	22.93 BC	42.85AB	1.59 DEF
Kénitra	1.07 CD	31.66 AB	51.36AB	2.99 CD
Cereal Main Effect Means ^b				
Bread Wheat	1.17 A	21.86 A	39.93 A	3.82 A
Durum Wheat	1.06 A	20.33 A	37.02 A	3.21 A
Barley	0.74 B	17.49 A	33.12 A	2.02 B

^a F - values : NS not significant ($P \leq 0.05$), * significant ($P \leq 0.05$), ** significant ($P \leq 0.01$), *** significant ($P \leq 0.001$).

^b Means within columns followed by the same letter are not significantly different ($P \leq 0.05$) : least significant difference test.

^c Ben Guerir and El Kelâa Srarhna are samples from the western and eastern parts of El Kelâa Srarhna province.

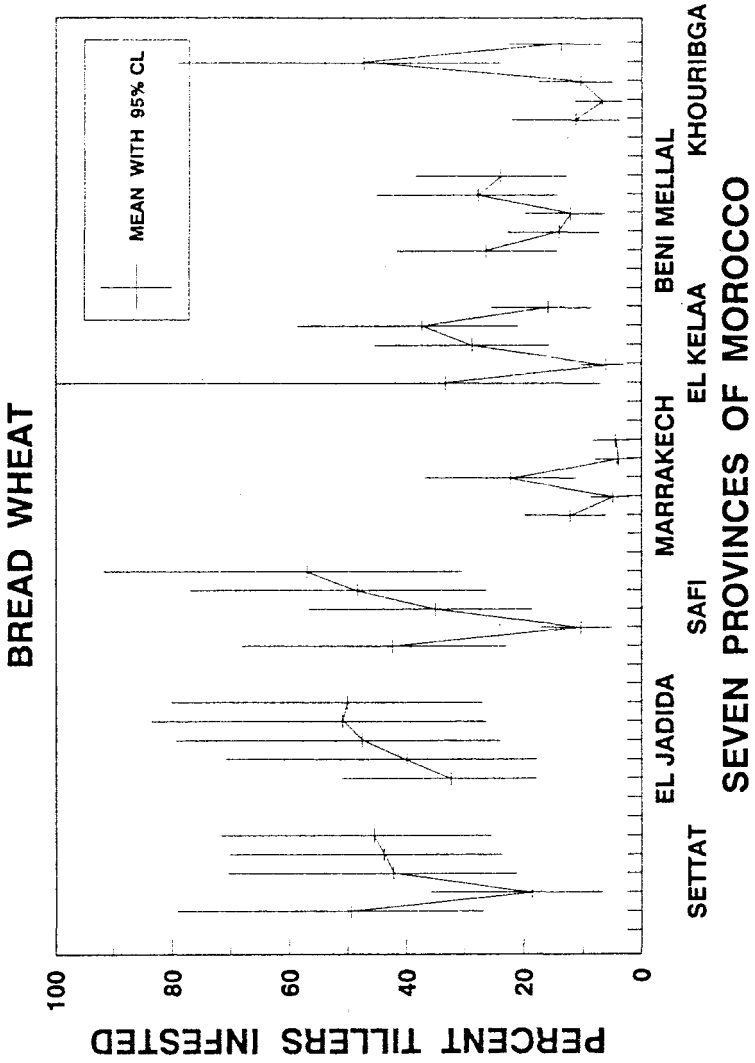


Fig. 2. : *Mayetiola* spp. infestations in bread wheat, expressed as mean percent tillers infested with 95 percent confidence limits over the five years of the survey in each of seven provinces.

BREAD WHEAT

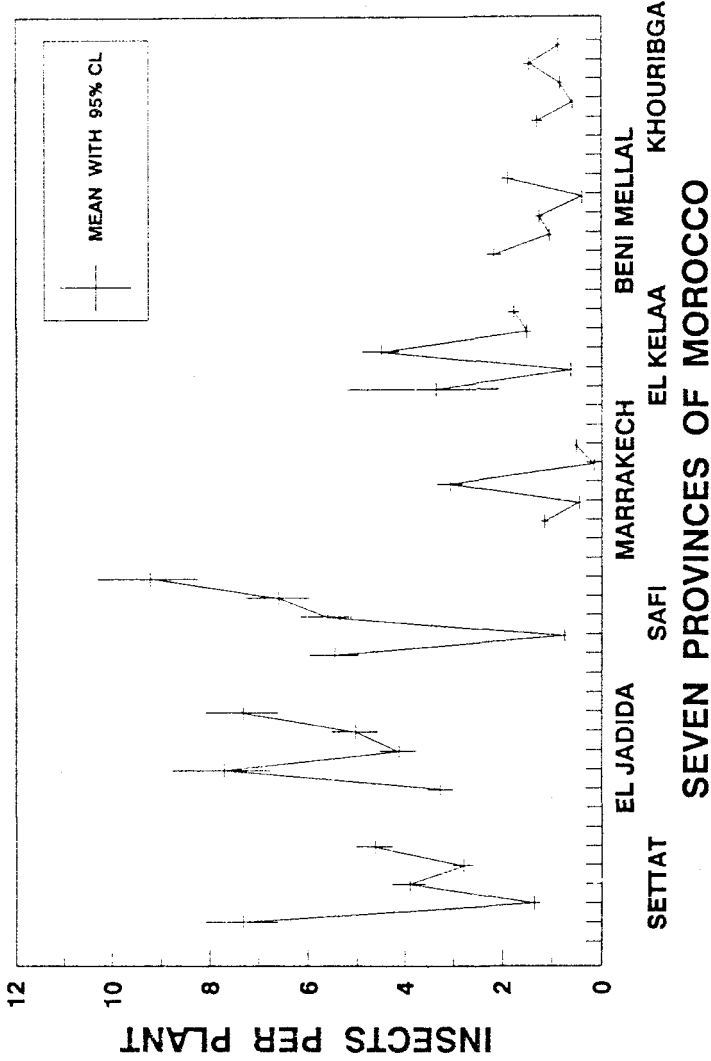


Fig. 3. : *Mayetiola* spp. infestations in bread wheat, expressed as mean insects per plant with 95 percent confidence limits over the five years of the survey in each of seven provinces.

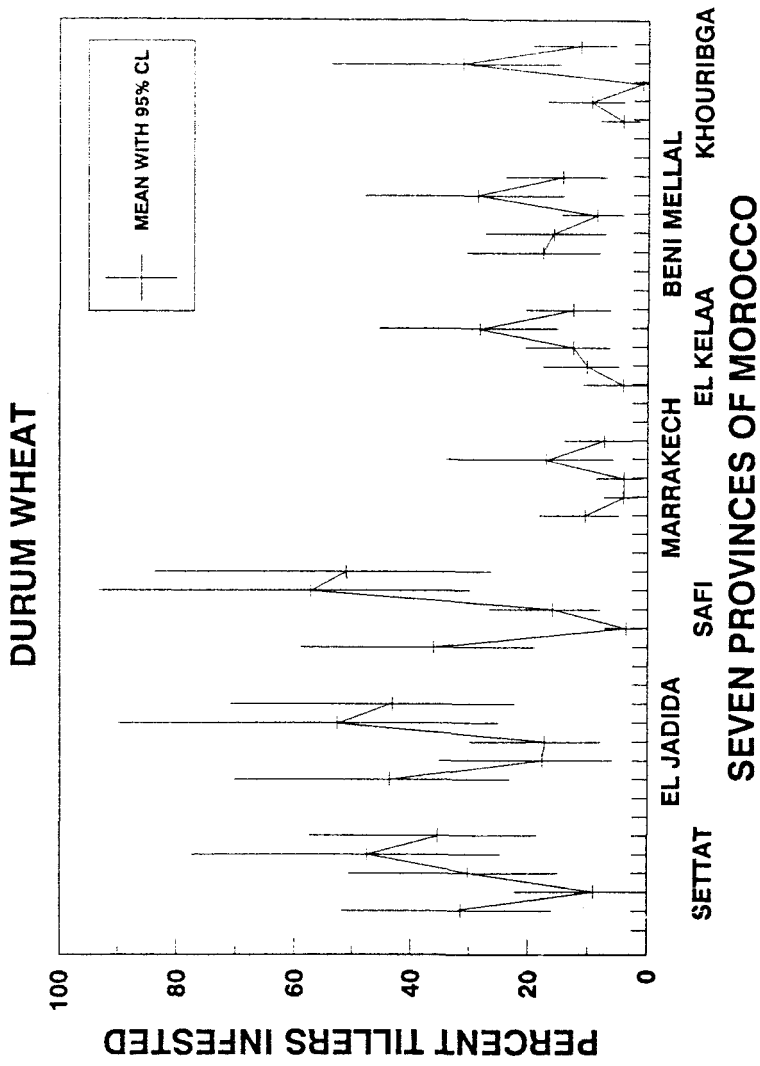


Fig. 4. : *Mayetiola* spp. infestations in durum wheat, expressed as mean percent tillers infested with 95 percent confidence limits over the five years of the survey in each of seven provinces.

DURUM WHEAT

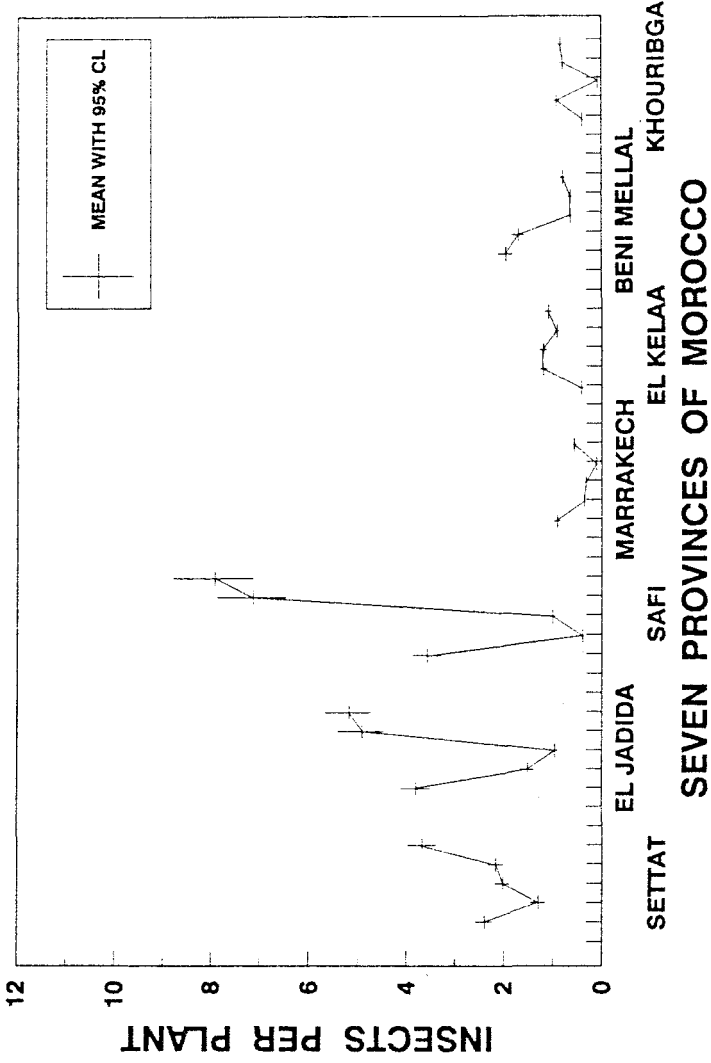


Fig. 5. : *Mayetiola* spp. infestations in durum wheat, expressed as mean insects per plant with 95 percent confidence limits over the five years of the survey in each of seven provinces.

BARLEY

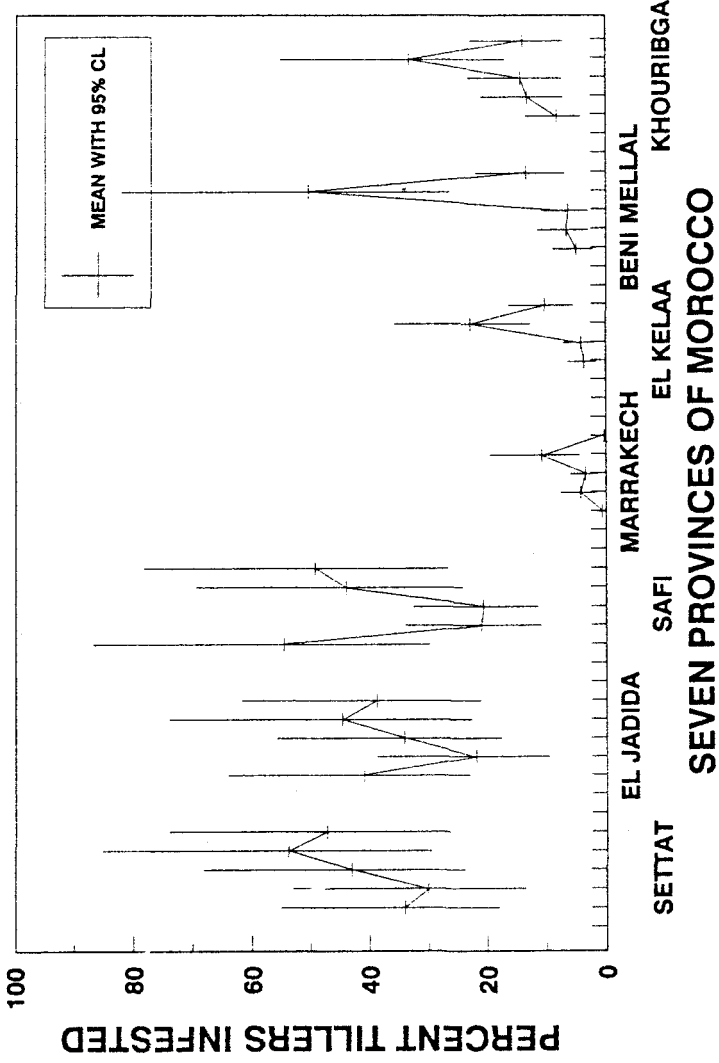


Fig. 6. : *Mayetiola* spp. infestations in barley, expressed as mean percent tillers infested with 95 percent confidence limits over the five years of the survey in each of seven provinces.

BARLEY

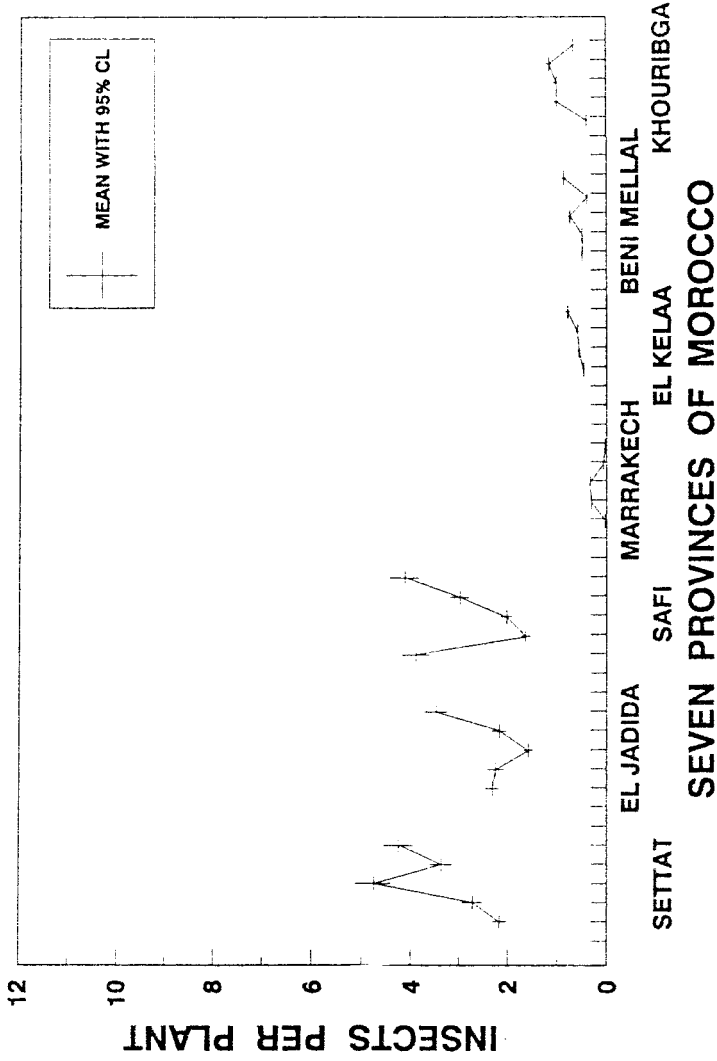


Fig. 7. : *Mayetiola* spp. infestations in barley, expressed as mean insects per plant with 95 percent confidence limits over the five years of the survey in each of seven provinces.

ABSTRACT

A total of 916 fields of bread wheat, durum wheat and barley were sampled in a five year survey for *Mayetiola* spp. in the westcentral semi-arid region of Morocco. An average of 88, 85 and 80 percent of the fields of the three cereals were infested and 65, 55 and 55 percent of them had economic infestations (>20 percent tillers infested). Statistical analysis indicates that infestations (percent tillers infested) were highest in the coastal provinces of Settat, El Jadida and Safi, lowest in Marrakech, and intermediate in the inland provinces of El Kelâa Srarhna, Beni Mellal and Khouribga. *Mayetiola* spp. infestations in barley were similar to those in bread wheat in the provinces of Settat, El Jadida, Safi and Khouribga, but they were lower in the provinces of Marrakech, El Kelâa Srarhna, and Beni Mellal. A 1990 survey into the nothern higher rainfall provinces indicated that *Mayetiola* spp. infestations in Khemisset, Meknès, Sidi Kacem and Kénitra were not significantly lower ($P \leq 0.05$) than those in the coastal provinces of Settat, El Jadida and Safi, where the highest populations were observed.

KEY WORDS : Hessian fly, *Mayetiola* sp., Cereals, Morocco, North Africa.

RESUME

Un total de 916 champs de blé tendre, de blé dur et d'orge ont été échantillonnés durant cinq années de surveillance de la Cécidomyie, **Mayetiola** Spp. Dans les régions semi-arides du Centre-Ouest du Maroc. En moyenne 88, 85 et 80 pourcent des champs des trois céréales ont été infestés et 64, 55 et 55 pourcent de ces champs ont eu des infestations économiques (> 20 pourcent de talles infestées). Les analyses statistiques ont indiqué que les infestations (pourcent de talles infestées) les plus élevées ont été observées dans les provinces côtières de Settat, El Jadida et Safi et les niveaux d'infestations les plus bas ont été enregistrés dans les provinces d'El Kelâa Srarhna, Beni Mellal et Khouribga.

Chez l'orge les infestations par **Mayetiola** Spp. ont été identiques à celles des blés tendres dans les provinces de Settat, El Jadida, Safi et Khouribga, mais plus faibles dans les provinces de Marrakech, El Kelâa Srarhna et Beni Mellal. En 1990, la surveillance dans les provinces bour favorable du Nord ont indiqué que les infestations de **Mayetiola** spp. à Khemisset, Meknès, Sidi Kacem et Kénitra n'ont pas été significativement plus faibles ($P \leq 0.05$) que celles des provinces côtières de Settat, El Jadida et Safi, où les populations les plus élevées ont été observées.

MOTS CLES : Mouche de hesse, **Mayetiola** Spp., Céréales, Maroc, Afrique du Nord.

ملخص

أخذت عينات من 916 حقلا من القمح الطري، القمح الصلب ثم الشعير، وتمت دراستها فيما يخص تواجد دودة هس، وكان هذا لمدة 5 سنوات شملت وسط غرب المناطق الشبه الجافة بالمغرب.

بما معدله 88٪ من حقول القمح الطري و85٪ من حقول القمح الصلب، و80٪ من حقول الشعير كانت مصابة بدودة هس بنسبة اقتصادية (أي أن أكثر من 20٪ من الأخطاء مصابة) قدرت ب 65٪ بالنسبة للقمح الطري، 55٪ بالنسبة للقمح الصلب والشعير. التحاليل الإحصائية أظهرت على أن الإصابات (نسبة الأخطاء المصابة) كانت عالية في الأقاليم الساحلية، لسطات، الجديدة، وآسفي، وضعيفة بمراكش، ومتوسطة في الأقاليم الداخلية لقلعة السراغنة، بني ملال وخربيكة. كما أن إصابات الشعير بدودة هس كانت شبيهة لما حصل للقمح الطري في أقاليم سطات، الجديدة، آسفي وخربيكة، لكن كانت أضعف في أقاليم مراكش، قلعة السراغنة وبني ملال. وقد أظهرت جولة 1990 الخاصة بالمراقبة لشمال المغرب على أن الإصابات بدودة هس بخميسات، مكناس، سيدي قاسم والقنيطرة لم تكن أقل من الإصابات بالأقاليم الساحلية لسطات، الجديدة وآسفي.

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Photo 3. Flaxseed and a second instar of Hessian fly, *Mayetiola destructor* (Say), on wheat. Note the loose attachment and the lack of galling around the flaxseed. (Photograph by L.L. Buschman)



Photo 4. Flaxseed of the barley fly, *Mayetiola hordei* Kieffer, on barley. Note the firm attachment and the galling of leaf tissue around the flaxseed. (Photograph by L.L. Buschman).